FEDERAL AGENCY OF RAILWAY'S TRANSPORT

Federal State Budgetary Educational Institution of Higher Education

«Petersburg State Transport University of Emperor Alexander I»

Faculty of «Transport and energy system»
Department of «Railway Rolling Stock»

Explanatory Notes of Course Project

by discipline: "Production and repair of rolling stock"

on the topic: "The technological process of troubleshooting wheelsets under operating conditions"

Specialty: "Rolling stock of railways "

Specialization: "Technology of production and repair of rolling stock"

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Abstract

The course project contains 24 pages of text, 6 figures, 2 tables and 2 drawings of A1 format.

The course project examines the technological process of troubleshooting wheelsets in operating conditions, namely the purpose of the device / equipment, the device and principle of operation, as well as the execution of technological documentation and the calculation of technical and economic efficiency from the implementation of the Technological process for troubleshooting wheelsets in operating conditions.

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Содержание

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Introduction

The main goals of development of the structure of the car facilities:

a. Transition to the predominant detection of car defects using automatic devices;

b. Elimination of repeated control and technical examinations;

c. Choice of strategy in the construction of cars and their reliability indicators;

d. Advanced diagnostic systems for detecting car malfunctions;

e. Development and implementation of resource-saving technologies.

Equipping the operating enterprises of the car facilitiy with specialized equipment and instrument of mechanization makes it possible to reduce the labor intensity of the repair of cars. Reducing the supply of cars for uncoupling repairs, and increasing the efficiency and quality of car maintenance.

One of the real way to solve the issues is the introduction of new information technologies. These technologies can not only facilitate the work of linear enterprises, reduce the amount of manual input of information, even to eliminate it completely. It is allowing to create an effective system for making management decisions at all levels.

According to operational data, in October 2019, almost 106,1 million passengers were transported on the infrastructure of Russian Railways Company ОАО “РЖД”, which is 0,4% more than in the same period from last year. From these, more than 9 million (+ 7%) passengers were sent on long-distance routes. Passenger turnover on the Russian Railways network since the beginning of 2019 has grown by 3% compared to last year and amounted to 114,6 billion pass-km, including long-distance passenger turnover - 85,8 billion pass-km (+ 2,7%)

1 The purpose of wheelsets and its role in ensuring the safety of train traffic

The wheelset is designed to guide the movement of the car along the track and to absorb all the loads transmitted from the car to the rails and back. Train traffic safety largely depends on the design, material, manufacturing and repair technology, as well as the quality of maintenance of wheelsets in operation. The design and maintenance of wheelsets affects the smoothness of the ride, the magnitude of the forces arising from the interaction of the car and the track, and the resistance to movement.

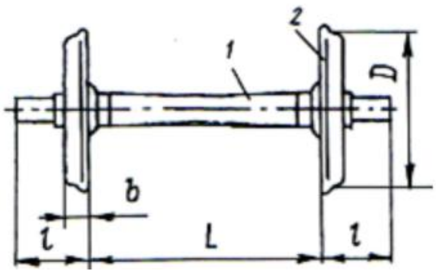

Figure 1. - Wheelset. 1 - Axle; 2 - Wheels

When a wheelset moves on rails, they withstand loads and rolls straight along the track. To ensure the safety of the train, the rolling circle of the wheel touches the rail.

2 Description of the main defects and malfunctions of wheelsets, analysis of the reasons for their occurrence

According to the regulatory document of ОАО "РЖД" (Russian Railway company) 1.20.001-2007 on the classifier of malfunctions of carriage wheelsets and their elements. The main defects and malfunctions of wheelsets are classified as follows.

Table 1. Description of wheelsets malfunction during operation

Class malfunctions	Fault group	The code of malfunctions	Cause of occurrence
1. Wear	11. Wheels	111. Even rolling	Metal deformation and abrasion of the rolling surface during the interaction of the wheel with the rail
		112. Uneven rolling	Inhomogeneity of metal properties on the rolling surface of the wheel
		113. Flange wear	Wheel flange friction
		114. Vertical undercut of the flange	Wheel flange friction
		115. Thin wheel tread	Normal natural wear on the tread surface of the wheel and repeated restoration of the tread surface profile by turning the tread.
		116. Ring workings	Inhomogeneous thermal effects on the surface layers of the metal of the wheel tread from brake pads and shoes

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			along the width of the contact zone
		117. Damage to the rolling surface of the wheel by electric current (corrugation)	Inhomogeneous thermal effects on the surface layers of the metal of the wheel tread from the action of an electric current
	12. Axle	123. Abrasion in the middle of the axis	Interaction with the longitudinal brake rods of the car due to non-compliance with the requirements for the maintenance of the brake linkage.
		124. Corrosion damage on necks and fillets of axles	Interaction with chemical agents, water and humidity.
		125. Wear of the journal of the axle due to the rotation of the inner ring of the bearing..	Rotations of the inner rings due to loss of interference fit on the axle neck
2. Thermomechanical damage	21. Wheels	211. Fatting “Added metal”	Intense plastic deformation of the metal during short-term jamming of wheels (skid).
		212 Creeper (flat place)	Slip of a wheel on a rail, causing local abrasion and deformation of the metal of the wheel
3. Mechanical damage	31. Wheels	311. Sharp run up of the ridge.	Operation of a wheelset on track sections with increased lateral wear of rails

		312. Circular bevel.	It is formed as a result of plastic deformation of the upper layers of the metal of the tread, which occurs under the action of normal and lateral forces, most often in curved track sections.
		313. Local widening of the tread.	Local broadening of the tread occurs as a result of plastic deformation of the metal due to the presence of a local internal defect under the action of cyclic vertical loads.
	32. Axles	321. Cold-hardening on the journal of the axle from the inner ring of the bearing	Local high contact pressures on the axle journal surface due to the presence of sharp edges and deviations from the geometry of the bore of the inner rings of the bearings.
		324. Damage to the thread M110x4 of the axes РУ1	The action of horizontal forces causing plastic deformation of the thread
	3. Wheelsets	331. Shifting wheel on the axle.	Violation of the technology of forming a wheel pair, mechanical stress during derailments of rolling stock.
		332. Bending of the axle of the wheelset.	Deformation from mechanical damage during derailments of the rolling stock.
4. Violation of the	1. Wheels	411. Cracks in the tread of	Ultimate accumulation of

complexity of the metal of an operational character		the wheel.	fatigue damage in the disc.
		412. Thermal cracks on the rolling surface of the wheel.	Cyclic repetition of intensive heating of the rolling surface of the wheel from the action of the brake shoe during braking and its subsequent cooling.
	2. Axes	422. Cracks on the journal and pre-under-hub parts.	Cyclic fatigue of the axle journal metal due to derailing of the rolling stock
		423. Cracks in the fillets of the journal and the under-hub part.	Cyclic fatigue of metal in fillets of journal and under-hub-part of the axle due to derailing of the rolling stock
6. Destruction in the form of metal chipping and spalling of separate parts	1. Wheels	611. Dents on the light spots of the creepers (flat place).	Chipping of the rolling surface areas formed as a result of metal hardening when the jammed wheelsets slide along the rails.
		612. Chipping due to fatigue cracks.	Chipping due to fatigue cracks is one of the types of natural wear of the metal, and occurs due to the depletion of the plastic reserve by the metal and the accumulation of fatigue damage.
		613. Dents along thermal cracks.	Formation of thermal microcracks on the rolling

			surface of the wheel tread as a result of repeated heating and cooling during braking, with further growth and consolidation of microcracks under the action of contact loads, followed by metal spalling.
		614. Chipping off the outer side surface of the wheel tread.	Development of fatigue subsurface cracks from internal defects of metallurgical origin under the action of operational loads.
		615. Breakaway of a circular bead of the outer side surface of the wheel tread.	Fatigue processes in the place of the influx and the action of hump retarders when dismantling cars on mechanized slides.
		616. Breakaway of the wheel flange.	Internal defects of metallurgical origin.Mechanical impact on the ridge when passing track arrangements (counter rails, guardrails, bends, etc.)
7. Destruction in the form of a fracture.	1. Wheels	711. Fracture of the wheel along the crack at the hub.	Wheel fatigue under cyclic loads, presence of stress concentrators in the form of surface or internal defects in the disc.
		712. Fracture of the wheel	Fatigue crack development due to the ultimate

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		along the crack at the tread.	accumulation of fatigue damage in the disc.
		713. Wheel break in the circumferential direction.	The development of a crack in the circumferential (longitudinal) direction, the cause of the formation of which may be operational damage or metallurgical defects in the wheel tread.
	2. Axle	721. Axis fracture due to the development of a crack in the neck.	Axle fatigue under cyclic loads, presence of metallurgical and operational stress concentrators.
		722. Axis fracture due to crack development in the pre-suction part.	Axle fatigue under cyclic loads, presence of metallurgical and operational stress concentrators.
		723. Fracture of the axle due to the development of a crack on the under-hub part.	Axle fatigue under cyclic loads, presence of metallurgical and operational stress concentrators.
		724. Axis fracture due to crack development in the middle part.	Axle fatigue under cyclic loads, presence of metallurgical and operational stress concentrators.
		725. Axle journal fracture due to axle box overheating.	Destruction of axlebox bearings and shift of axleboxes, leading to jam of bearings and their heating

3. Technological process for identifying the malfunction of wheelsets during operation

There are many types of wheelset malfunctions. On the course project will identify only one malfunction as an sample. Chipping on the rolling surface.

Maintenance of wheelsets

1. maintenance of wheelsets and axleboxes, control of the parameters of wheelsets under the cars is carried out in accordance with the requirements of the Instruction to the car inspector
2. at stations of formation and disbandment of trains, on the move at the time of arrival, after arrival and before departure;
3. at stations where the train schedule provides for a parking lot for technical inspection of cars;
4. at the points of preparation of wagons for transportation and before being put on the train;
5. after crashes, train accidents, collisions of rolling stock
6. during the current uncoupling repair of wagons.
7. technical control of wheelsets and their elements.

Permissible values of the parameters of wheelsets in operation:

- uniform wheel rolling - no more than 9mm;

- wheel flange thickness - 25 ... 33mm;

- wheel rim thickness - not less than 22mm.

If there are defects on the rolling surface of the wheel (dents, sliders, uneven rolling), the wheel tread thickness is measured at the location of the defect;

- the distance between the inner side surfaces of the tread of the wheels for wheelsets with axles:

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РУ1 and РУ1Ш - 1437 ... 1443mm,

РВ2Ш - 1439 ... 1443mm. 4. Selection of the technological equipment and tooling necessary for the repair.[1]

Measurement of the distance between the inner side surfaces of the rims of the wheels is carried out only at the unloaded wheelset. It is forbidden to put into operation and allow wagons with defects and malfunctions of wheelset elements to be used in trains.

- cracks in any part of the wheelset axle;

- traces of contact with the electrode or electric welding wire in any

  axle and / or wheel parts;

- cracks in any part of the wheel;

- by displacement of the wheel on the axle-bearing part;

- weakening the fit of the wheel on the axle.

A sign of a weakening of the wheel landing on the axle is a paint rupture at the hub along the entire perimeter of the wheel joint of a corrosive strip (rust) or oil from under the hub on the inner side of the wheel;

- uneven rolling (if detected) - more than 2mm.

- vertical undercut of the wheel flange;

- a pointed roll of the ridge

Wheelsets with dents on the rolling surface of wheels up to 1mm are not rejected regardless of their length. A crack in a chink or delamination going deep into the metal is not allowed;

[1] РУ1 and РУ1Ш - Russian wheelsets type

4. Technological equipment for troubleshooting wheelsets during operation

4.1 Equipment purpose

The complex of technical measurements (КТИ «Комплекс») is designed to measure the geometric parameters of the rolling surface of wheelsets in order to identify the degree of wear and quantify defects of solid-rolled wheels on the move of the train, register wheelset malfunctions and promptly transfer the information received to the nearest service station.

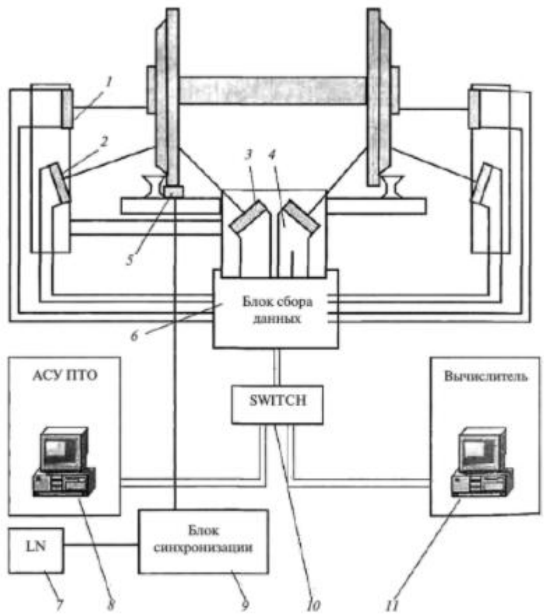
Figure 2. Automation of the complex of technical measurements «КОМПЛЕКС» on the rail.

The technical solution for the control of the geometric parameters of the wheelset is based on the principle of self-scanning of the wheels using a set of active measuring sensors of the triangulation type[2] . Automatic remote contactless monitoring of rolling surface defects of carriage wheels while the train is in motion.

Types of defects will be revealed by the КТИ «Комплекс» (read: KTI "COMPLEX"):

1. Creeper (flat place)
2. Added metal, displacement of metal on the wheel tread of the height exceeding the allowable limit
3. Uneven rolling
4. Undercut flange, etc.

The system consists of the following units and blocks.



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[2] Triangulation (Latin triangle) is a method of measuring the distance to a controlled object by using the properties of a right-angled triangle and the laws of trigonometry. In this case, the length of only one side of the triangle and one of its corners are measured, and the lengths of the other sides are obtained based on the laws of trigonometry.

Figure 3. Block diagram of the KTI:
1 - right axle box sensor; 2 and 3 - external and internal wheel sensors;
4 - temperature sensor for thermal stabilization systems;
5 - magnetic pedal; 6 - data collection unit; 7 - train presence signal
on the site - LN; 8 - АСУ ПТО (read: ASU PTO); 9 - synchronization unit; 10 - АРМ ПТО (read: AWP PTO) operator (SWITCH switch); 11 - calculator (personal computer)

Axle box sensors – designed to measure the surface profile of the inspection and fastening covers of the axle-box unit.

Temperature sensors – designed to control the temperature conditions inside the sensor. The data acquisition module is an electronic device designed to wait for a long-range warning signal about an approaching train. Upon receipt of a long-range warning signal, the monitoring system is put into readiness, communication with the "Server" is established. Communication is carried out over the Ethernet network. While the trains are moving, the MSD completes the required number of axle acquisition cycles. After passing the train, all data blocks for wheelset control are transferred to the Server PC, the system goes into the train standby mode. "Server" - is a server for the accumulation of information for receiving, storing and processing information coming from the MSD, processes the measurement results for monitoring the wheelset and calculates the necessary parameters for its subsequent transfer to the automated control system of the PTO.

Workstation of a security operator (АРМ ПТО) – is an automated workstation based on a PC, which, upon request, receives measurement results from the "Server", displays control results in a convenient form for the operator, and displays statistics data. In addition, the operator's workstation allows for online monitoring of the state of the measuring device, for promptly changing its settings (when debugging the system). The main operating mode of the AWP is automatic, without the participation of the operator, with the issuance of alarm messages (to the monitor and printer) about the registered defective axles with the exact indication of the train number, serial and inventory number of the car and the serial number of the axle in the car.

Synchronization unit– designed to process signals from two magnetic pedals (to isolate the signal) and to process a long-range warning signal with the issuance of appropriate interrupts to the MCD.

Magnetic pedal – generate an impulse at the moment the wheelset passes over it.

Table 2. Technical characteristics of KTI “KOMPLEKS” (КТИ «КОМПЛЕКС»)

Measurements are taken at train speeds	up to 60 km / h
Measurement error of linear dimensions	up to 0.5 mm
Working temperature range	from –50 to +50 ° C
Supply voltage	220 V
Power consumption	no more than 3 kW

Dust and moisture proof version with thermal stabilization

This workstation is intended:

- to provide information on the last train (track number, call time, number of cars, total weight, etc.);
- display on the monitor screen of alarming information on defective wheelsets, axles, etc .;
- display all results of measurement of axles in a convenient form for the operator;
- formation and display of statistical reports for the selected control period.

4.2 The principle of operation of the KTI

The technical solution for the control of the geometric parameters of the wheelset is based on the principle of self-scanning of the wheels using a data collection unit and a set of active measuring sensors of the triangulation type. Upon receipt of a long-range warning signal, the data collection unit puts the monitoring system in readiness and establishes communication with the "calculator".

During the passage of the train, the unit performs the required number of cycles of data collection on wheelsets, taking into account the speed of the train. For this purpose, each wheel is scanned in parallel and independently by two measuring sensors (inner and outer). Subsequent joint processing allows you to determine the profile in the wheel reference system, and then calculate the values of the required geometric parameters.

The resulting image is continuously processed by a computer, which determines the state of the entire system (readiness for operation, measurement and test modes, the presence of a blocking effect) and monitors the performance of all measuring modules. The rail pedals at the entrance and exit of the installation send signals to the base unit about the passage of the train through the measuring section.

Subsequent joint processing makes it possible to determine the parameters of the wheelset. The operator's screen displays a visualization of the wheelset profiles with a defect, which is compared with the baseline.

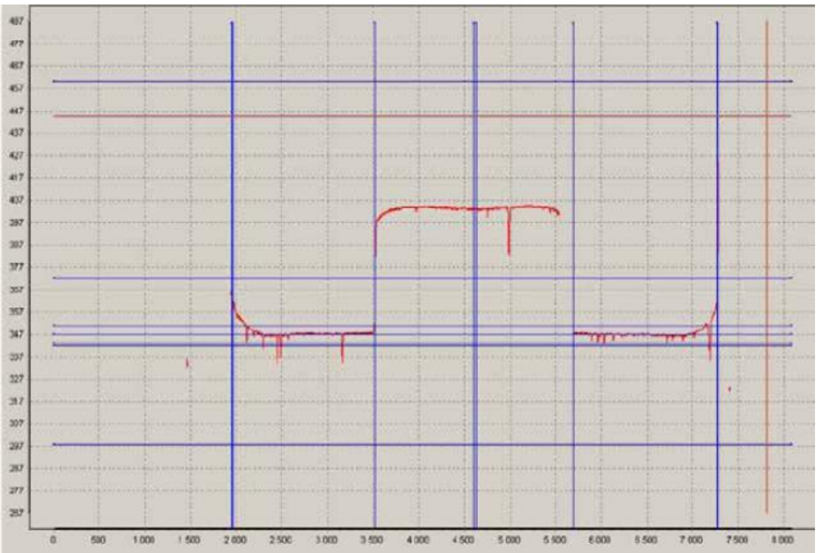

Figure 4. Signal from internal sensors

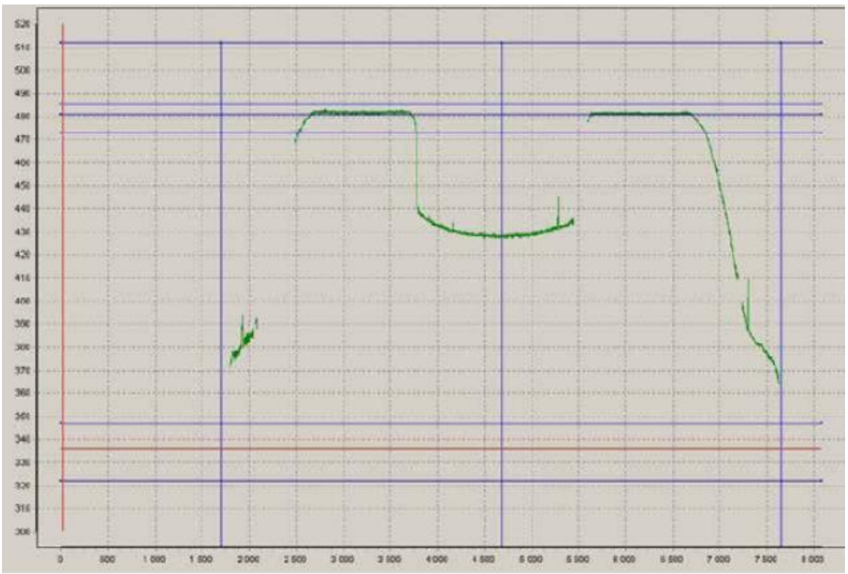

Figure 5. Signal from external sensors

Based on the results of the analysis, decisions are made on the possibility of further operation of the wheelset. The method of calculating the controlled parameters based on the profile basically repeats the approaches laid down in the contact meters of similar parameters. The results of measuring the geometric parameters of t he wheelsets of the passing train are accumulated in a computer - "calculator" located in the room (container), and then transmitted via the TCP / IP protocol to the automated control system of the PTO.

The results of all measurements in the form of a table are displayed on the workstation of the operator of the ЦПУ (CPU (central control center)) of the SPTO. Alarming information is highlighted in the table in red on the monitor of the receiving computer of the "Complex". To identify the train number (if the СКАТ (SKAT) software fails), the video image of the locomotives is placed on the right margin of the monitor using the software menu to increase the image size in order to determine the locomotive number.

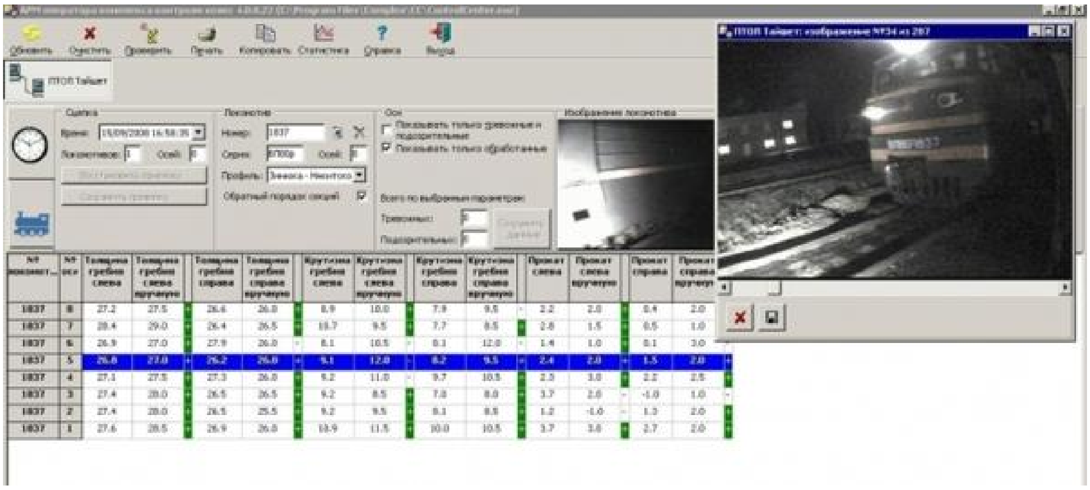

Figure 6. Fragment of the APM (read: AWP) working window with the results of the wheelset geometry control

The operator of the PTO central control room receives the date and time of the train's entry and exit to the control post, the ordinal number of the axle from the head, a sign of a wheelset malfunction with an indication of the rejection parameter and its actual measured value.

5. Calculation of the technical and economic efficiency from the introduction of the technological process for detecting the malfunction of wheelsets and the used of technological equipment

The use of new equipment or technologies in production helps to increase production efficiency, reduce the labor intensity of the manufacturing or repair process, improve working conditions and safety at the site. The introduction of new technology, in comparison with the old one, gives a greater economic effect, expressed, ultimately, in an increase in profits, profitability of production, in a decrease in production costs per unit of production. The course project assesses the economic effect of the introduction of equipment and devices used to repair a given unit, improve the technology of repair or manufacture of cars, or their individual units.

In accordance with the Methodological Recommendations for Evaluating the Economic Efficiency of Investments (approved by Russian Railways in 2005), all financial investments must undergo a preliminary assessment. For this, indicators of economic effect (cost reduction) and economic efficiency are used. The main indicators used to calculate the efficiency of investment projects are:

–Net income (NP);

–Net Present Income (NPV);

–Internal rate of return (IRR);

–The need for additional financing (other names of PF, project cost, risk capital);

–Indices of profitability of costs and investments;

-payback period;

–A group of indicators characterizing the financial condition of an enterprise - a project participant.

The wage fund in the operation of detecting a malfunction of wheelsets is determined by the formula, $ФОТ$:

$$ФОТ = ЧТС * Н_и * В_л + ЧТС * Н_и * П, \qquad (1)$$

Where $ЧТС$ – ч.т.с. Inspector wage fund when a wheelset malfunction is detected during operation is 47.70 rubles.

$Н_и$ – time norm 4.6 man-hour,

$В_л$ – length of service, = 15%,

$П$ – bonus, = 50%.

$ФОТ$ =47,70*4,6*0,5+47,70*4,6*0,15=109,71+32,91=142,62 rub..

Payroll charges are 26,7% and are equal to 38,07 rubles, respectively.

The cost of detecting a malfunction of wheelsets in the maintenance equipment is determined by the formula:

$$S_{экс} = ФОТ + Н \qquad (2)$$

Where $Н$ – charges for ФОТ, $Н$=38,07 rub.

$S_{экс}$ =142,62+38,07 = 180,69 rub.

The wage fund for the implementation of a complex of technical measurements of wheelsets (1) is:

$ФОТ$ =30*0,7*0,3+30*0,7*0,15=9,45 rub.

where $ЧТС$ – workstation operator (ПТО operator) 30 rub.,

$Н_и$ – time norm 0,7 man.-hour,

$В_л$ – length of service, $В_л$=15%,

$П$ – bonus, $П$=30%.

Payroll charges are 26,7% and are equal to 2,52 rubles, respectively.

The cost of work when introducing a complex of technical measurements of wheelsets is:

$$S_{раб}=9,45+2,52=11,97 \text{ rub.}$$

Calculation of the annual economic effect from the introduction of a complex of technical measurements of wheelsets according to the formula:

, $$Э = (S_{экс} - S_{раб})*n \qquad (3)$$

where $S_{экс}$– the cost of troubleshooting wheelsets in operation,

$S_{раб}$ – cost of work for introducing a complex of technical measurements of wheelsets,

n – the annual volume of wagons production during service (TO), n=1000.

$$Э=(180,69-11,97)*1000=168720 \text{ rub.}$$

The payback period for capital investments is:

$$S_{ок} = \frac{C_{ст}}{Э}, \qquad (4)$$

where $C_{ст}$ - book value of complex automated diagnostic for measuring geometric parameters of wheelsets of cars "Complex"

, $C_{ст}$=2500000 rub.

Payback period:

$$S_{ок}=2500000/168720=14 \text{ year}$$

6. Constructive and technological measures to increase the service life of wheelsets

The service life of a wheelset is influenced by: loads acting on it in operation; non-compliance with the requirements of the technological process during its manufacture; imperfection of the existing method of connecting the wheels to the axle. As mentioned above, the resulting mechanical damage to the mating surfaces reduces the fatigue strength and reliability of the wheelset.

In order to avoid damage to the axle bearings during the pressing of the wheels (press damage) on the German railways (DBAG), strength tests were carried out on samples, as well as on finished parts with a coating applied by the method of ion implantation. Investigation of the processes of development of press damage on specimens and wheelsets showed that they can be successfully avoided. If a positive result of the completion of operational tests of wheelsets protected by ion implantation is obtained, it is planned to introduce this method in the technology of manufacturing and repairing wheelsets.

Improving the performance and extending the service life of the wheelset undoubtedly also depends on the reliable characteristics of its component parts. According to a number of experts, the use of new materials is of great importance.

It is believed that promising materials for the manufacture of wheels are bainitic steel with a low carbon content, in which martensitic transformations are impossible, and the so-called superalloys based on nickel or nickel with iron, in which martensitic transformations are also impossible and which have high heat resistance. Wheels made from nickel or nickel-iron superalloys do not slip or slip due to their exceptional resistance to high temperatures. Both of these materials can be fabricated using conventional manufacturing processes, although it should be noted that superalloys are more difficult to machine than conventional wheel steels.

Although low carbon bainitic steel cannot prevent the occurrence of slides, it hardly develops pits or cracks. As a result, bainitic steel wheels can have a significantly longer service life, as the amount of metal removed with each reprofiling is reduced. For clarity, an additional performance test cycle was run on UK Railways.

The use of devices (lubricators) for lubricating the flanges of the wheels allows in most cases to expect an increase in the service life of the wheels up to 2 times. Lubrication is especially widely used on North American railways. According to American experts, in the case of using grease, the wear rate of rails is reduced by 10 times, and of wheels made of high-hardness steel by 5 times.

There is also a noticeable trend towards an increase in the service life and a decrease in the life cycle costs of wheels due to a decrease in the number of turns and, accordingly, metal removal during their execution, in other words, towards an increase in the proportion of "pure" (natural) operational wear. However, it should be borne in mind that with longer turning intervals, it is necessary to take into account an important factor of fatigue stress accumulation in the wheels, which can increase the degree of risk from the point of view of road safety.

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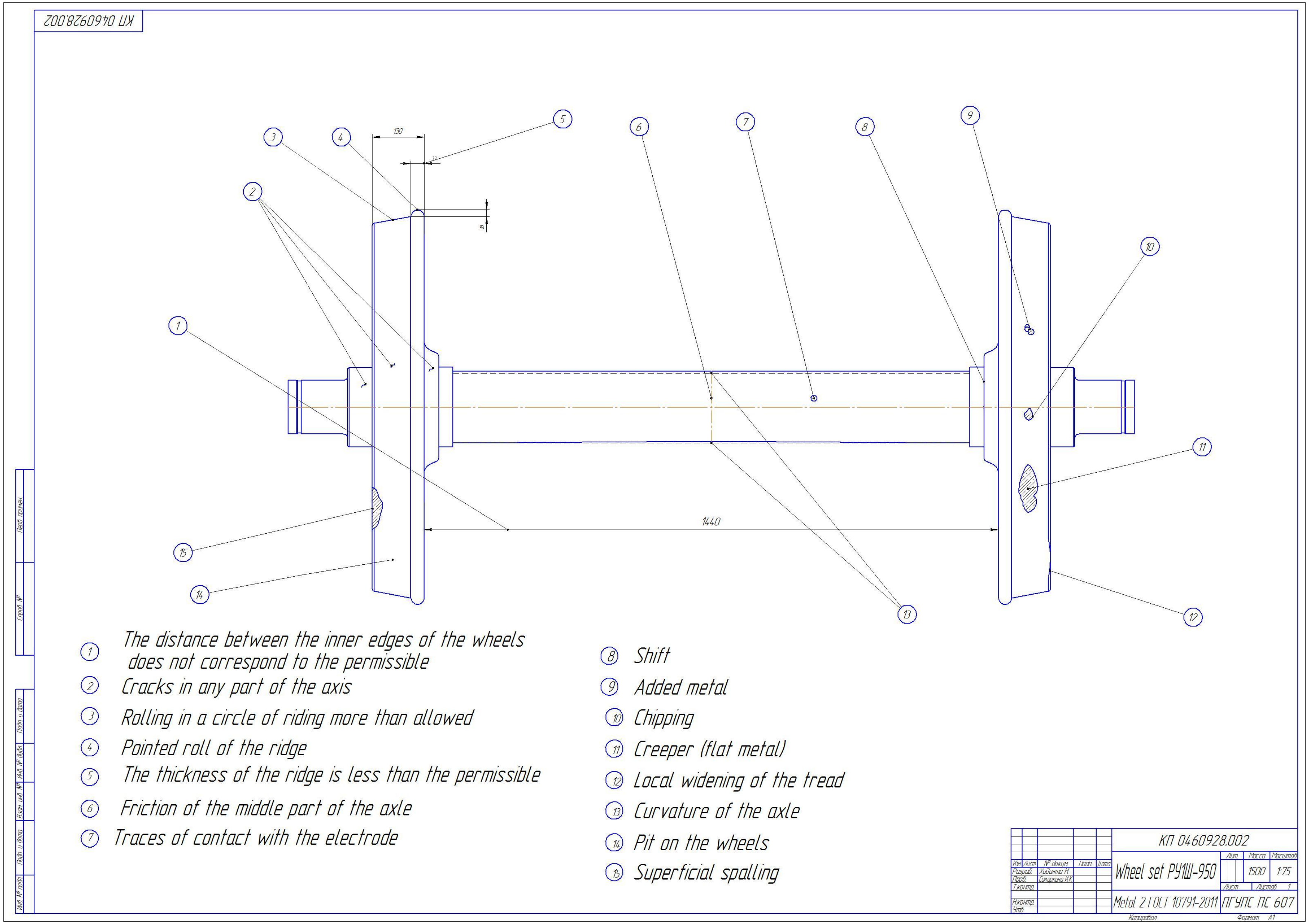
ATTACHMENT 1



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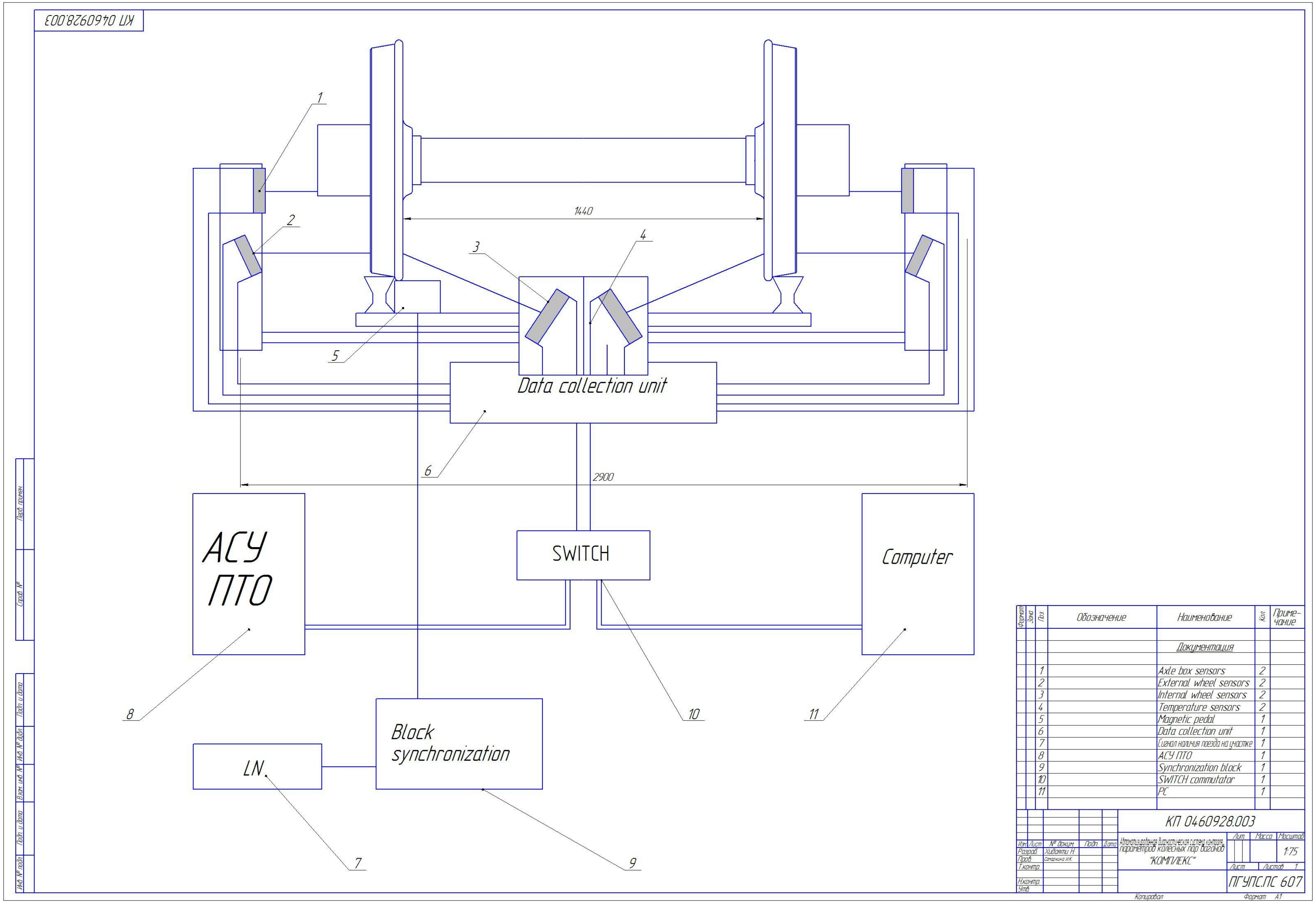

Формат	Зона	Поз.	Обозначение	Наименование	Кол.	Приме-чание
				Документация		
		1		Axle box sensors	2	
		2		External wheel sensors	2	
		3		Internal wheel sensors	2	
		4		Temperature sensors	2	
		5		Magnetic pedal	1	
		6		Data collection unit	1	
		7		Сигнал наличия поезда на участке	1	
		8		АСУ ПТО	1	
		9		Synchronization block	1	
		10		SWITCH commutator	1	
		11		PC	1	